MASTER OF SCIENCE
IN
OPERATIONS RESEARCH

A MULTI-YEAR AMMUNITION PROCUREMENT MODEL FOR DEPARTMENT OF THE NAVY NON-NUCLEAR ORDNANCE

John H. Bruggeman-Major, United States Marine Corps
B.S., United States Naval Academy, 1991
Master of Science in Operations Research-September 2003
Advisor: W. Matthew Carlyle, Department of Operations Research
Second Reader: Gerald G. Brown, Department of Operations Research

The Navy Non-nuclear Ordnance Requirements (NNOR) process determines annually the preferred inventory levels for most Department of the Navy munitions. This process is unrestricted by cost. Procurement planners must then apply current budgetary constraints to determine actual purchasing recommendations. This report introduces a metric for quantifying the capability provided by a given inventory of a munition. It then describes an optimization model, the Assessment and Investment Model (AIM), which will generate multi-year purchasing recommendations in order to maximize the capability of the inventory subject to constraints in terms of budget, industrial base, maintenance, and NNOR requirements.

The Navy Ammunition Logistics Center (NALC) is working to replace the current process of generating munitions procurement recommendations. The effort documented in this report was initiated by, and has the support of, NALC as a potential decision-support tool. Initial results show that AIM procurement recommendations are superior to recommendations generated by the current process and will result in a more combat-effective munitions inventory for any given (and, currently, almost $2 billion) Department of the Navy weapon procurement budget.

KEYWORDS: Munitions Procurement, Optimization, Measure of Capability

AN EXPLORATORY ANALYSIS OF LITTORAL COMBAT SHIPS' ABILITY TO PROTECT EXPEDITIONARY STRIKE GROUPS

Motale E. Efimba-Lieutenant, United States Navy
B.S., United States Naval Academy, 1997
Master of Science in Operations Research-September 2003
Advisor: Thomas Lucas, Department of Operations Research
Second Reader: LCDR Russell Gottfried, USN, Department of Operations Research

This thesis uses an agent-based simulation model named EINSTein to perform an exploratory study on the feasibility of using Littoral Combat Ships (LCSs) to augment or replace the current defenses of Expeditionary Strike Groups (ESG). Specifically, LCS's ability to help defend ESGs in an anti-access scenario against a high-density small boat attack is simulated. Numbers of CRUDES (CRUiser, DEStroyer, Frigate) ships are removed and LCSs are added to the ESG force structure in varying amounts to identify force mixes that minimize ship losses. In addition, this thesis explores various conceptual capabilities that might be given to LCS. For example, helicopter/Unmanned Combat Aerial Vehicles (helo/UCAVs), stealth technology, close-in high volume firepower, and 50+ knot sprint capability. Using graphical analysis, analysis of variance, and large-sample comparison tests, it is found that being able to control aircraft is the most influential factor for minimizing ship losses. Stealth technology is another significant factor, and the combination of the two is highly effective in reducing ship losses. Close-in high volume firepower is effective only when interacting with helo/UCAVs or stealth. Fifty+ knot sprint capability is potentially detrimental in this scenario. An effective total sum of CRUDES ships and LCS is between five and seven platforms.

KEYWORDS: EINSTein, LCS, Littoral Combat Ship, ESG, Expeditionary Strike Group, Assured Access, Agent-based Simulation

SELECTIVE OFFLOAD CAPABILITY SIMULATION (SOCS): AN ANALYSIS OF HIGH DENSITY STORAGE CONFIGURATIONS

Frank W. Futcher-Lieutenant Commander, United States Navy
B.B.A., George Washington University, 1991
Master of Science in Operations Research-September 2003
Advisor: Kevin R. Gue, Graduate School of Business and Public Policy
Second Reader: Arnold H. Buss, Modeling, Virtual Environments, and Simulation Institute

Future sea bases, such as the Maritime Prepositioning Force (Future), will serve as key distribution nodes and must be able to sustain forces ashore and selectively offload supplies from storerooms quickly and efficiently. Current MPF ships maximize the available cargo storage onboard and have little ability to selectively offload supplies. To make selective offload a reality, MPF(F) requires lower stowage densities and new technologies to efficiently move items, especially for those supplies needed in direct support of forces ashore. The difficult questions are how dense and in what configurations MPF(F) storerooms can be packed, and how items should be retrieved in order to selectively offload supplies and provide acceptable response time.

The trade-off between storage density and mean retrieval time in a dynamic environment for different storage densities and configurations in notional storerooms aboard a future sea base is analyzed. Two demand scenarios and two different retrieval rules to determine how each storage configuration responds to retrieval requests over time are examined. Results provide insight into the types of storeroom configurations that provide the best mean retrieval times and how a simple retrieval rule can significantly reduce mean retrieval time under certain demand conditions.

KEYWORDS: Selective Offload, Stowage and Retrieval, High-density Stowage, Very High Density Storage Systems, Sea Basing, Storage Configurations, Storage Density, Sea-Based Logistics, SBL, Maritime Prepositioning Force, MPF, Future, MPF(F), Sustainment, Sea Base, Automated Storage and Retrieval Systems, AS/RS

UPGRADABLE OPERATIONAL AVAILABILITY FORECASTING TOOL FOR THE U.S. NAVY P-3 REPLACEMENT AIRCRAFT

Michael C. Margolis-Captain, United States Marine Corps
B.S., Mary Washington College, 1996
Master of Science in Operations Research-September 2003
Advisor: Arnold H. Buss, Modeling, Virtual Environments, and Simulation Institute
Second Reader: David A. Schrady, Department of Operations Research

The P-3 Orion maritime aircraft has been the U.S. Navy's primary maritime patrol aircraft since its fleet introduction in 1962. Naval Air Systems Command (NAVAIR) has determined that the P-3 fleet has sufficiently aged to warrant a replacement. The replacement aircraft is currently undergoing the conceptual phase of development and it is during this period that NAVAIR is interested in evaluating the trade-off between operational availability and the associated cost to achieve this operational availability. This thesis developed a simulation tool that was used to investigate relationships that affect cost and operational availability of the new (notional) aircraft on a deployment. The simulation tool was exercised for select scenarios in order to gain insights into the value of investing funds in additional aircraft versus the value of investing funds in increased component reliability. The simulation was developed to be very flexible and extensible, enhancing its value for future analyses. Required data inputs into the simulation tool are formatted utilizing a new technology called Extensible Markup Language (XML), which facilitates use of the data in nearly all computer software packages. The model is robust in nature and can be applied to a wide variety of aircraft.

KEYWORDS: Trade-off Analysis, Operational Availability, Readiness Based Sparing, Cost Analysis, P-3 Orion

EXPLORATORY ANALYSIS OF SUBMARINE TACTICS FOR MINE DETECTION AND AVOIDANCE

Terrence M. Nawara-Lieutenant, United States Navy
B.S., United States Naval Academy, 1996
Master of Science in Operations Research-September 2003
Advisor: Steven E. Pilnick, Department of Operations Research
Second Reader: Arnold H. Buss, Modeling, Virtual Environments, and Simulation Institute

This thesis provides an initial analytical basis for Tactical Decision Aids in submarine mine detection and avoidance (MDA). Five aspects of submarine MDA are studied. First, a network optimization model plans the best route through a minefield based on prior surveys of bottom clutter (NOn-mine Mine-like Bottom Objects, or NOMBOs). If a submarine is trying to avoid going through a minefield, the second model helps the submarine decide how far to back up if it detects a mine. A third model calculates minimum safe standoff distance for initiating submarine maneuvers around a given mine. This model takes into account submarine maneuvering characteristics and sensor error in the case of onboard sensor detection, or both navigation and mine location errors in the case of reported mine positions. The fourth aspect of the submarine MDA problem uses simulation to study the probability of safe transit based on alternative MDA tactics, various mine and NOMBO densities, and various probabilities of detection. Finally, the simulation examines the probability that a given MDA tactic will result in gridlock, i.e., the probability that a single attempt to penetrate the minefield is blocked by mines or NOMBOs.

KEYWORDS: Mine, Minefield, NOMBO, Mine Warfare, Mine Detection and Avoidance, Simulation, Poisson, Reactive, Path Planning, Obstacle Avoidance, Navigation, Mission Planning, Percolation

MAXIMIZING THE STABILITY OF AN ENSEMBLE OF CLOCKS

Juan J. Ruiz-Lieutenant Commander, Spanish Navy
B.S., Universidad Complutense de Madrid, 1992
Master of Science in Operations Research-September 2003
Advisor: Alan Washburn, Department of Operations Research
Second Reader: Paul Sanchez, Department of Operations Research

Atomic clocks provide "stable" signals that are mainly used to generate time scales and to measure differences of time between events. Each atomic clock can individually be characterized according to the stability of the scale it produces.

Due to the stochastic behavior of each clock, usually clock ensembles are used to build more stable time scales. This process requires basically two steps. First, it is required to individually characterize each time source to identify the particular noise components present. Second, a measure of performance is required in order to derive an algorithm based on it to properly "weigh" this particular clock in the process of creating a combined scale.

In this thesis, both problems are faced using an operations research approach: each clock is modeled, analyzed, and characterized by a time-dependent measure of performance related to its intrinsic stability, and optimally combined to produce a more stable combined time scale. The optimality criterion is directly related to the spectral characteristics of the noise sources present.

KEYWORDS: Characterization of Atomic Clocks, Frequency Stability, Allan Variance

A SIMULATION OF THE I3 TO D REPAIR PROCESS AND SPARING OF THE F414-GE-400 JET AIRCRAFT ENGINE

Eric J. Schoch-Lieutenant Commander, United States Navy
B.S., Iowa State University, 1991
Master of Science in Operations Research-September 2003
Advisor: Arnold H. Buss, Modeling, Virtual Environments, and Simulation Institute
Second Reader: CDR Kevin J. Maher, USN, Department of Operations Research

The F/A-18E/F is the latest multi-mission tactical aircraft to enter United States Naval Service. It generates power via two F414-GE-400 engines, each of which is composed of six modules. In addition to a new aircraft model and engines, a new concept, the I3 to D Repair Process, is being used for F414-GE-400 module and engine repair. In the I3 to D Repair Process, the intermediate level no longer repairs modules. Instead, the depot level performs all module repairs. This thesis develops and exercises a simulation of the I3 to D Repair Process for the F414-GE-400 by incorporating simulated F/A-18E/F flight schedules and engine failures to populate the repair cycle. The simulation provides operational availability (A0) and probability to spare the repair process given an infrastructure and sparing profile. Three previous years of module failures and depot repair times are used to calibrate the model. Simulation results for the baseline studied showed the distinct influence of certain input parameters. Aircraft service entry time had only a relative short-term effect on A0. Cannibalization of engines among F/A-18s improved A0. Scheduled maintenance dramatically impacted A0. Finally, of all the components of depot repair turn around time (RTAT), "In Work" and "Other" influenced A0 the most. The simulation was also used to examine the impact of varying build windows and depot RTAT. It allows easy changes of input parameters to be made so that a multitude of effects on A0 and probability to spare the repair process can readily be studied.

KEYWORDS: F/A-18, Hornet, F414-GE-400, Jet Aircraft Engine, Simulation, Simkit, Operational Availability, Repair Process, I3 to D

MULTIVARIATE ANALYSIS OF THE EFFECT OF SOURCE OF SUPPLY AND CARRIER ON SHIPPING TIMES FOR ISSUE PRIORITY GROUP ONE (IPG-1) REQUISITIONS

Brian G. Schorn-Lieutenant Commander, United States Navy
B.S., Carnegie Mellon University, 1993
Master of Science in Operations Research-September 2003
Advisor: Samuel E. Buttrey, Department of Operations Research
Second Reader: CDR Kevin J. Maher, USN, Department of Operations Research

The objective of this thesis is to examine the effects of source of supply and carrier on shipping times of high-priority requisitions to primary destinations of Navy units in the Pacific Theater and Persian Gulf. The focus was primarily on determining whether source of supply, carrier, and the interaction of these two factors have an effect on shipping times of high-priority requisitions. "Source of supply" refers to Department of Defense supply depots and "carrier" refers to shippers, such as Federal Express® and DHL Worldwide Express®.

This study uses ordinary least square (OLS) linear models, generalized linear models (GLMs) and nonparametric methods to explore the structure of the historical requisition datasets. OLS linear models were found to be inadequate, but both the GLMs and nonparametric tests proved to be valid and yielded results from which inferences could be made. According to the GLMs and nonparametric tests, source of supply has a statistically significant effect on shipping times of high-priority requisitions, but carrier does not. The GLMs also indicated that there is no significant interaction between source of supply and carrier.

KEYWORDS: Requisition Shipping Time, Multivariate Linear Regression, Generalized Linear Models, Nonparametric Analysis, Kruskal-Wallis Rank Sum Test

USING AGENT-BASED DISTILLATIONS TO EXPLORE LOGISTICS SUPPORT TO URBAN, HUMANITARIAN ASSISTANCE/DISASTER RELIEF OPERATIONS

Eric Wolf-Captain, United States Marine Corps
B.A., University of Nevada at Las Vegas, 1995
Master of Science in Operations Research-September 2003
Advisors: Susan M. Sanchez, Department of Operations Research
Niki Goerger, TRAC-Monterey
Second Reader: MAJ Lloyd Brown, USA, TRAC-Monterey

There are two motivations for studying Humanitarian Assistance/Disaster Relief (HA/DR) operations. First, the Marine Corps will be a first-responder in the future. Second, logistics support takes on a primary role. This thesis identifies the potential for using agent-based models to support logistical decision-making in an urban, HA/DR environment. A simulation is developed using Map Aware Non-uniform Automata (MANA). The scenario depicts a relief convoy with security attachment, operating on urban terrain. The convoy moves to an HA/DR site where they distribute food to neutrals (locals) who have made their way to that site.

Data farming is coupled with a Latin Hypercube design of experiment to explore very large data space. Forty variables are identified. Six hundred and forty different design settings are established and each setting is replicated 50 times, producing a 32,000-point dataset. Regression is used to fit several models. The conclusions from this thesis suggest: coupling intelligent designs with data farming is effective at exploring large data space; mission success in HA/DR operations may depend on only a handful of factors; understanding local communications is the key to mission success; and success cannot be determined based solely on the factors the convoy controls.

KEYWORDS: Agent-based Models, Humanitarian Assistance, Disaster Relief, MANA, Project Albert, Supercomputing, Latin Hypercube, Design of Experiment, Convoy Operations, Food Distribution, Measures of Effectiveness, Multiple Linear Regression